Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 81 (2014) 634 – 640

Procedia Engineering

www.elsevier.com/locate/procedia

11th International Conference on Technology of Plasticity, ICTP 2014, 19-24 October 2014, Nagoya Congress Center, Nagoya, Japan

Tube necking extrusion principle and forming process of trailer rear axle

Chunguo Xu* , Guangsheng Ren, Yongqiang Guo, Weiwei Ren, Ya Zhang

Plasticity forming technology center, Beijing research institute of mechanical & electrical technology, No.18 xueqing road, Haidian district, Beijing, China

Abstract

The rear axle which undergoes the heavy and alternating load is the key parts on the rear bridge of trailer truck. The rare axle with integrated structure has become the main developing trend because of reducing vehicle weight and increasing load capacity. After reviewed the status of the forming process, this paper researched the forming process of the integer rear axle on numerical simulation and experiment, and present a highly efficient new forming process. For tube necking process, the relation between main parameters such as semi-cone angle, temperature, forming velocity, friction coefficient and limited necking coefficient were studied. To improve the ability of a necking coefficient, the way of heating with a temperature gradient were used. The simulation result shows that it can greatly increase the necking coefficient. Based on theoretical analysis and numerical simulation, the forming process of rare axle with integrated structure were studied, experiment were done and the sample of rear axle were obtained. The experiment results were coincident with the simulation. The deformation and wall thickness increase law of necking process was obtained. The new forming process by end heating with temperature gradient was presented. It could be used to produce rear axle rapidly and less energy consumption.

Selection and peer-review under responsibility of the Department of Materials Science and Engineering, Nagoya University

Keywords: Rear axle; Necking coefficient; Extrusion; Temperature gradient

1. Introduction

With the development of China's automobile industry, trailer and container car entered a rapid development period and have a broad market prospects, along with the demand for trailer axle is increasing. Meanwhile, the development of environmental friendly vehicles and precision forming technology for the rear axle is the core competitiveness of enterprises.

Selection and peer-review under responsibility of the Department of Materials Science and Engineering, Nagoya University
doi:10.1016/j.proeng.2014.10.052

* Corresponding author. Tel.: +8601082415107; fax: +8662933753.
E-mail address: xuchg@jds.ac.cn

The rear axle as shown in Fig. 1 is the key parts on the rear bridge of trailer truck, which bear the heavy and alternating load. The part must have a high bending strength, torsional stiffness and fatigue. The rear axle with integrated structure has become the main developing trend because of reducing vehicle weight and increasing load capacity. Now there are two forming process of the rear axle with integrated structure, that is spinning forming and extrusion forming. In contrast, extrusion is better than the spinning in product quality and process control. However, there are some problems in the extrusion forming process should be solved. In order to present a high efficient technology, tube necking process, tube wall thick increasing method and heating method were studied deeply.

Fig. 1. Location and shape of rear axle.

2. Effect of necking factors on tube used for forming rear axle

The total length of Integrated axle exceed 2000mm, the length of forming part about 900mm; After necking, the diameter of the end section reduced nearly doubled compared with the original diameter, the maximum thickness of the rear axle is 35mm that is proximity three times thicker than the original. From above what we have described about the products, it is not difficult to find that some difficulties in forming process. Firstly, both ends of workpiece have large deformation extent and strictly thickness. It is difficult to control the tube inner shape because of metal deformation at that place being free condition. Secondly, regional wall thickness is too large to adopt normal multiple forming process.

In order to obtain a new forming process, the basic forming laws of this size tube used in rear axle need to be analyzed, which has not previously involved in the domestic research. The systematically theoretical analysis and research of tube necking on 20Mn2 high tensile strength material, especially for law of wall thickness variation in the necking process (20Cr adopted for simulation material model because it is very similar to 20Mn2 in the composition and performance). To analyze the effect of process parameters on formability, three-dimensional finite element simulation software and the actual experiment were used to understanding the universal law of necking.

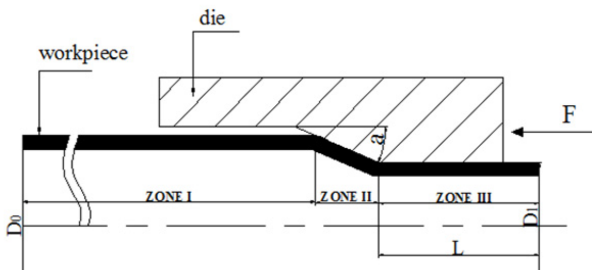

Fig. 2. Schematic diagrams of necking deformation.

Fig. 2 shows schematic diagrams of necking deformation .There are many factors affect the deformation such as semi-cone angle, temperature, forming velocity, friction factor and necking coefficient, etc. Necking coefficient is a key factor in all parameters. The necking coefficient usually expressed as" m" is measured as below.

$$m = D_1 / D_0 \,, \tag{1}$$

Degree of deformation can be achieved by one necking step mean the minimum necking coefficient m_{min}.

Through a series of orthogonal test for tube necking process, the relation between main parameters such as semi-cone angle, temperature, forming velocity, friction factor and limited necking coefficient were studied. The parameter for the simulation include the following aspects: μ (0.05-0.3), T (20-1200 °C), m_{min} (0.7-0.82), *a* (*10-30°*), v (20-100 mm/s).

Nomenclature

m	necking coefficient of tube
μ	friction factor
a	semi-cone angle
D_0	original diameter of tube
D_1	diameter after deformation
L	length after deformation
F	forming loads
v	forming velocity

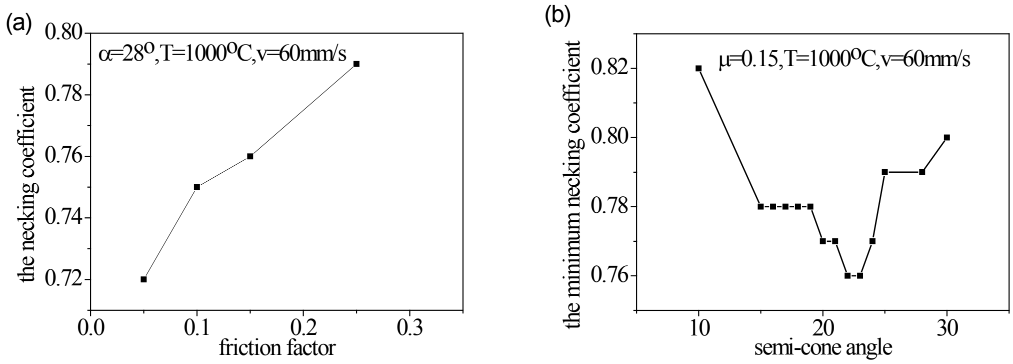

Fig . 3. (a) Effects of friction different factors on necking coefficient and (b) relationship between semi-cone angle and m_{min}.

Fig. 3(a) shows the effects of friction different factors on the minimum necking coefficient. 4 sets of friction factor commonly used were selected. With the decrease of friction factor, can effectively increase the necking deformation extent. Relationship between semi-cone angle and the minimum necking coefficient is shown in Fig. 3(b). Research shows the best semi-cone angle at about 23°.

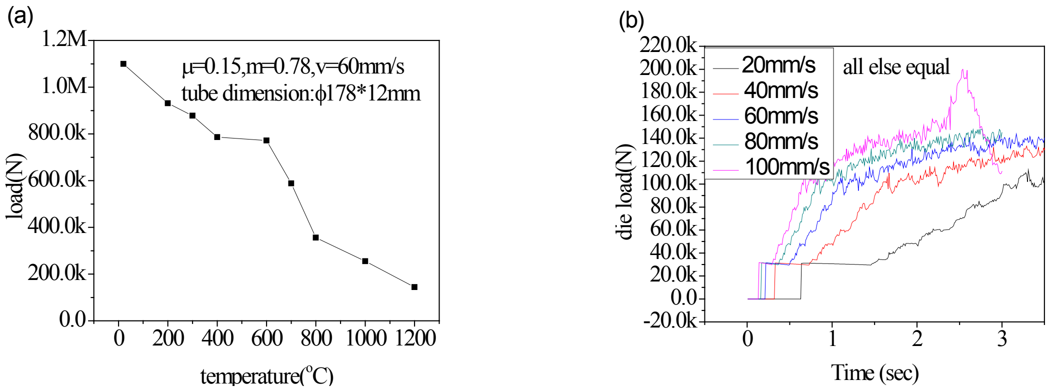

Fig. 4. (a) Relationship between temperature and forming load and (b) influence of forming velocity.

Fig. 4(a) shows the relationship between temperature and forming load, the data when the tube just appeared Instability phenomenon was selected in the necking coefficient 0.78conditions, The forming load must be below the curve in order to ensure the completion of forming. If the load over the curve as shown in Fig. 4(a) in a given temperature, the instability will be appeared. So it can be used to measure the maximum load that transmitted load without instability of tube at different heating temperatures. Fig. 4(b) illustrates the Influence of five forming velocity. The faster the forming velocity, the greater the deformation resistance is. In addition, the forming velocity cannot be chosen too slowly because of thermal serious loss caused by the thin wall thickness. So, the velocity had better choose between 60 and 80 mm/s.

By concrete analysis of wall thickness increasing, the influence of wall thickness variation is very small for forming velocity and friction factor. By contrast, the wall thickness variation has great changes as the conditions of semi-cone angle and necking coefficient change. What is more, the smaller minimum necking coefficient, the thicker wall thickness. At the same time, the larger semi-cone angle, the thicker wall thickness. In fact there was Interaction among the various factors listed above. Obviously the smaller minimum necking coefficient is the biggest factor in wall thickness increasing. From what has been discussed above, we may safely draw a conclusion that we need to control the minimum necking coefficient to get a big increase in wall thickness after forming.

3. Increasing tube deformation extent with a temperature gradient

In the necking process, the part could be divided three regions: (**I**) supporting region,(**II**) forming region and (**III**) deformed region as shown in the Fig.2. The deformation pattern are different in region area, the elastic deformation mainly occurred in **I** and the plastic deformation start at the entrance of **II.** The test of m_{min} is that without plastic deformation at **I** area. Through the analysis of each region, we found some way improving the ability of a necking coefficient.

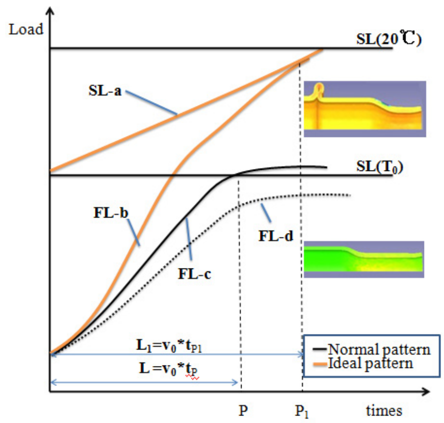

Fig. 5. Sketch of load conditions.

For SL curve in the Fig. 5 means the maximum bearing load in supporting part of tube in forming process, namely plastic deformation of ZONE **I** just occurs in the forming load. The load of the SL is close to the fixed value that only related to the material properties under the same conditions of temperature. The FL curve (FL-b, FL-c, FL-d) is interpreted as the forming load changes with time. Normally, FL-d and SL (T_0) conditions in tube necking can be completed, but the allowable deformation of tube is very small. If forming load over this point, deformation instability will appear at ZONE **I**, that is to say, the deformation extent cannot be increased further, so the maximum deformation of tube located in the P point, where is also the position of the minimum necking coefficient. If the product need to achieve large deformation and long deformation length, it is impossible in the traditional condition. How to increase the bearing capacity of ZONE **I** is the key to solve this problem. According to the above analysis, FL-d and SL (T_0) conditions need to be changed. The ideal conditions may be shown as the two curves SL-a and FL-b in Fig. 5, that can achieve large deformation extent by increasing bearing capacity of the ZONE **I**. So the way of heating with a temperature gradient can be used for making normal pattern into ideal conditions, which effectively improve the ability of the necking coefficient. The following simulations and experiments also validate above standpoint.

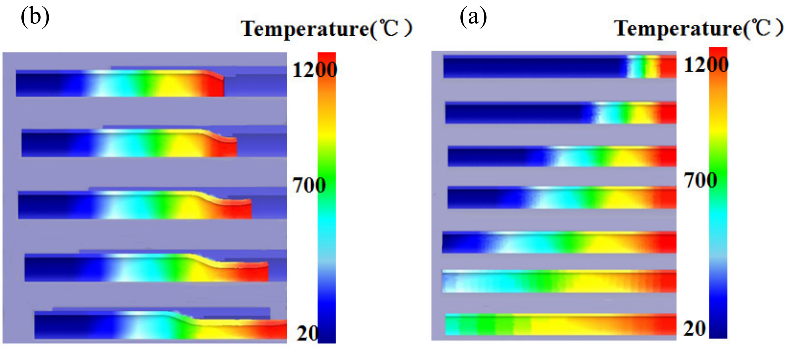

Fig. 6. (a) Necking process with temperature gradient and (b) seven kinds of temperature gradient.

Fig. 6(a) shows the tube with a temperature gradient necking process , the heating systems are designed to study how the temperature distribution of work-piece to influence on the tube necking process by using numerical simulation. Fig. 6(b) illustrates seven workpieces with kinds of temperature gradient. According to the length and diameter of necking, different temperature gradient heating methods for forming are selected.

The minimum necking coefficient can reach 0.71-0.72 by using temperature gradient heating method, under the same forming conditions, only 0.76 through the traditional heating way. The degree of deformation is increased by 10%. It provides theoretical guidance for the forming process of rear axle with integrated structure. The necking ability can be improve obviously by using temperature gradient methods with suitable temperature transition during integer axle extrusion, which makes it possible to make the integer axle more convenient production by reducing the forming step and increasing the production efficiency.

4. New forming process of rear axle

Through the research of temperature and deformation also found that wall thickness in designated areas is increased by changing temperature distribution. Combined with the law of wall thickness changes and necking forming rule, the forming of rear axle with integrated structure are analyzed by three-dimensional finite element simulation software.

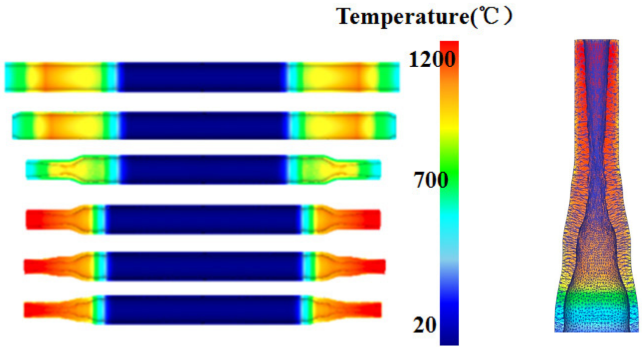

Fig. 7. New forming process of rear axle.

Based on theoretical analysis and numerical simulation, the forming process of rear axle with integrated structure were analyzed .The new two step forming process by using temperature gradient heating was presented as shown in Fig. 7. As can be seen, the part where need increasing wall thickness has reached the requirements of the drawings. So, it is feasible to realized new forming process by simulation. However, the surface quality and the metal flow of inner cavity of the tube forming cannot control in the process of simulation, it should be studied by specific experimental.

First of all, experiment was carried out for two kinds of heating which is Traditional Heating and Temperature Gradient Heating. From the Fig. 8 we can see that the simulation results are in accord with the experimental results. The workpiece with temperature gradient heating achieve larger deformation compared with conventional heating.

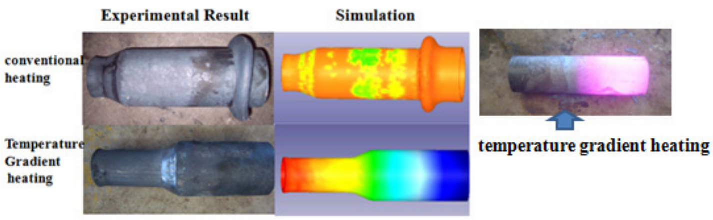

Fig. 8. Simulation and experimental results.

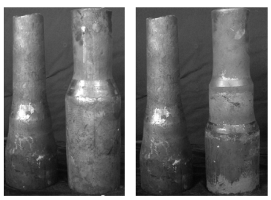

Fig. 9. Sample of rear axle.

In the next place, the new two step forming process by using temperature gradient heating already tested by the practical experiments. Fig. 9 shows the sample of rear axle obtained by two step forming in the experiment. It has been testified that this forming process is practicable.

5. Conclusions

Through the study of the forming parameters such as semi-cone angle, temperature, forming velocity, friction coefficient and limited necking coefficient, the optimum technological parameter is selected to realize the forming of rear axle.

To improve the ability of a necking coefficient, new heating method that presents the variation of temperature gradient was proposed. It is possible to make the integer axle more convenient production by reducing the forming step and increasing the production efficiency.

The heating method is a key factor to influence necking during integer axle extrusion. It realizes the large deformation of the tube. But that is only part of the method, the other half is increasing tube wall thickness in the set region. Based on theoretical analysis and numerical simulation, the forming process of rear axle with integrated structure is proposed. The new forming process is indeed feasible by heating with temperature gradient in the experimental results .So, we can effectively increasing production efficiency and reducing energy consumption by reducing forming step and heating times in the actual production of axle, to a certain extent, the research can improve the manufacture level of rear axle with integrated structure for industrial application.

References

Guihua Liu. Yongqiang Guo. Zhi Jiang.Influence of Heating Models on Necking Deformation during tube Extrusion Process. Advanced Materials Research Vols. 189-193 (2011) 1778-1781.

K. Ye. The Design and Technology of the Multi Necking Die for the Thin-Wall Part, Die andMould Iindustry, 2002(12):262-263.

K.Srinivasan and P.Venugopal. Formability Limit in Container less (Open Die) Extrusion ofCommercial Purity Titanium Rods and Tubes. Materials and Manufacturing Process.2008,23: 47-351.

T.Wang. Tube plastic forming technology. Machinery Industry Press, 1997, 146-149.